3.2.5 Air Quality Related Values

Air quality related values (AQRV) (such as flora, fauna, soil, water, cultural resources, odor and visibility) can be impacted by air pollution. For the purpose of this analysis, the discussions will focus on visibility, deposition of N and sulfur, and lake chemistry.

Visibility

Interagency monitoring of protected visual environments (IMPROVE) has measured visibility in national parks and wilderness areas in the United States since the 1980s. There are seven IMPROVE aerosol monitoring stations in Wyoming: Bridger Wilderness (near Pinedale), Yellowstone National Park, North Absaroka Wilderness (near Dead Indian Pass), Cloud Peak, Brooklyn Lake, Boulder Lake and Thunder Basin. Some of the best visibility monitored in the contiguous United States is at the Bridger Wilderness station in western Wyoming.

Visibility can be expressed in various units, including SVR (standard visual range) and dv (deciview). SVR is the distance wherein one can see the color, contrast and texture of an object. Figure 3-15 shows daily visibility in the Bridger Wilderness as standard visual range. From 1988 through 2010, visibility in the Bridger Wilderness stayed about the same, ranging from ten miles on the haziest days to 230 miles on the clearest days. Visibility is similar at Yellowstone National Park (Figure 3-16), North Absaroka (Figure 3-17), Cloud Peak (Figure 3-18), Brooklyn Lake (Figure 3-19), and Rocky Mountain National Park (Figure 3-20). SVR is less on the clearest days in Thunder Basin (Figure 3-21) and Boulder Lake (Figure 3-22).

Visibility can also be expressed in dv, a measure of perceived changes in visibility. One dv is defined as a change in visibility that is just barely perceptible to an average person, about a 10% change in light extinction.

Monitored aerosol concentrations are used to reconstruct visibility conditions for each day monitored, ranked from clearest to haziest; conditions are reported in three categories:

- 20% clearest—Mean visibility for the 20% of days with the best visibility
- Average—Annual mean visibility
- 20% haziest—Mean visibility for the 20% of days with the poorest visibility

Figure 3-23 shows annual visibility in Bridger Wilderness from 1989 through 2010 (using the most current data available from IMPROVE). Visibility on the 20%clearest days varies from 160 to 200 miles. Average visibility varies from 110 to 150 miles. Visibility for the 20% haziest days varies from 70 to 100 miles. Visibility on the clearest days has improved since 1989. The Bridger IMPROVE station was sited to monitor general air quality representative of the Bridger area, rather than the maximum impact from gas development.

Figure 3-24 shows annual visibility in Yellowstone National Park from 1991 through 2010. Visibility on the 20% clearest days varies from 135 to 200 miles, average visibility varies from 95 to 145 miles, and visibility on the 20% haziest days varies from 60 to 95 miles. Visibility has improved since 1991.

Figure 3-25 shows annual visibility in North Absaroka from 2002 through 2008. Visibility on the 20% clearest days varies from 180 to 200 miles, average visibility varies from 120 to 135 miles, and visibility on the 20% haziest days varies from 60 to 90 miles. Visibility has stayed about the same over this period.

Figure 3-26 shows annual visibility in Cloud Peak from 2003 through 2010. Visibility on the 20% clearest days varies from 190 to 200 miles, average visibility varies from 130 to 150 miles, and visibility on the

20% haziest days varies from 60 to 95 miles. Visibility on hazy days has improved, although visibility on average and clear days has stayed about the same during this period.

Figure 3-27 shows annual visibility in Rocky Mountain National Park from 1991 through 2010. Visibility on the 20% clearest days varies from 150 to 200 miles, average visibility varies from 100 to 130 miles, and visibility on the 20% haziest days varies from 50 to 80 miles. Visibility has improved since 1991.

Atmospheric Deposition

Atmospheric deposition, which refers to the processes by which air pollutants are removed from the atmosphere and deposited on terrestrial and aquatic ecosystems, is reported in the document as the mass of material deposited on an area in one year (kilogram per hectare per year [kg/ha/yr]). Air pollutants are deposited by wet deposition (precipitation) and dry deposition (gravitational settling of particles and adherence of gaseous pollutants to soil, water, and vegetation). The following substances are deposited:

- Acids—Such as sulfuric acid (H_2SO_4) and nitric acid (HNO_3). This acid deposition is sometimes referred to as acid rain.
- Air toxics—Such as pesticides, herbicides, and volatile organic compounds (VOC).
- Nutrients—Such as nitrate (NO_3^-) and ammonium (NH_4^+).

The estimation of atmospheric deposition is complicated by contributions to deposition by rain, snow, cloud water, particle settling, and gaseous pollutants. Deposition varies with precipitation, which, in turn, varies with elevation and time.

Wet Deposition

The National Atmospheric Deposition Program (NADP) assesses wet deposition by measuring the chemical composition of precipitation (rain and snow). The natural acidity of rainwater is represented by a range of pH values from 5.0 to 5.6 (Seinfeld 1986). There are nine NADP stations in Wyoming: Snowy Range, Sinks Canyon, Pinedale, Yellowstone National Park, Grand Tetons, Brooklyn Lake, South Pass, Gypsum Creek and Newcastle.

The mean annual precipitation pH in Pinedale from 1982 through 2011 ranged from 4.9 to 5.5, indicating some acidification of precipitation during that period (Figure 3-28). Data for Sinks Canyon and South Pass show similar values of precipitation pH (Figure 3-29).

Dry Deposition

Dry deposition refers to the transfer of airborne gaseous and particulate material from the atmosphere to the Earth's surface by gravitational settling. The Clean Air Status and Trends Network (CASTNet) measures dry deposition and concentrations of SO_2, HNO_3, sulfate (SO_4^{2-}), NO_3^-, and NH_4^+. There are three CASTNet[1] stations in Wyoming: Pinedale, Yellowstone National Park and Centennial with data available from the 1990's through the present. These data for Pinedale, Centennial, and Yellowstone National Park show dry deposition values in Pinedale to be low and steady for all pollutants, although HNO_3 deposition ranged from 0.75 to 2.5 kg/ha/yr in Pinedale.

[1] Because of the chemistry of nitrogen- and sulfur-containing compounds and the manner in which data are collected, it would not be appropriate to compare CASTNet and WARMS data with ambient air quality standards. In addition, there are questions concerning the lack of consistency in the WARMS data.

Mean annual CASTNet concentrations of HNO_3 are less than 0.2 ppb in Pinedale (Figure 3-30). Typically, HNO_3 concentrations range from 0.02 to 0.3 ppb in remote areas and from 3 to 50 ppb in urban areas (Seinfeld 1986). Although HNO_3 concentrations in Pinedale are well below urban levels, concentrations are in the high range of those typical in remote areas. Mean annual concentrations of NO_3^- are less than 0.1 ppb at Pinedale. Typically, NO_3^- concentrations are about 0.2 ppb in remote areas and one ppb in urban areas (Stern 1973). Mean annual concentrations of NH_4^+ are less than 0.4 ppb in Pinedale. Typically, NH_4^+ concentrations are 0.3 ppb in remote areas and 1.4 ppb in urban areas (Stern 1973). The concentrations of N compounds are about the same in Centennial (Figure 3-31) and in Yellowstone National Park (Figure 3-32).

Mean annual concentrations of N compounds measured by the Wyoming Air Resources Monitoring System (WARMS) at Pinedale from 2002 through 2010 are below 3 $\mu g/m^3$ for NO_3^- and NH_4^+, below 0.6 $\mu g/m^3$ for HNO_3, and below 0.8 $\mu g/m^3$ for total nitrate. These concentrations indicate particulate nitrate and nitric acid concentrations typical for remote areas, slightly elevated ammonium concentrations (2003-2008), and elevated concentrations of total nitrate (Figure 3-33).

More recent SO_2 data, as well as SO_4^{--} data, were collected by CASTNet in Pinedale through 2011 (Figure 3-34). Concentrations of SO_2 are less than 0.3 ppb in Pinedale. Typically, SO_2 concentrations range from 1 to 10 ppb in remote areas and from 20 to 200 ppb in urban areas (Seinfeld 1986). Thus, SO_2 concentrations in the planning region are less than concentrations typical of remote areas. Mean annual concentrations of SO_4^{--} are below 0.1 ppb in Pinedale. Typically, SO_4^{--} concentrations are about 0.6 ppb in remote areas and about 2.5 ppb in urban areas (Stern 1973). The SO_4^{--} concentrations in the region are well below urban levels and equal to levels typical in remote areas. Concentrations of sulfur compounds are similar in Centennial (Figure 3-35) and Yellowstone National Park (Figure 3-36).

Figure 3-37 shows that mean annual WARMS concentrations of SO_2 and SO_4^{--} in Pinedale were less than 1.0 $\mu g/m^3$ from 2002 through 2010. These concentrations indicate sulphur compound concentrations typical for remote areas.

Total Deposition

Total deposition refers to the sum of airborne material transferred to the Earth's surface by both wet and dry deposition. Total deposition level of concern (LOC) has been estimated by the National Park Service (NPS) to be 1.5 kg/ha-year for N and 3 kg/ha-year for sulfur (NPS 2011).

Figures 3-38 to 3-43 compare total deposition near Pinedale, Yellowstone National Park and Centennial with the total deposition LOCs set by the NPS. Total N deposition near Pinedale ranged from 1.2 to 1.9 kg/ha-year from 1982 to 2010, and was greater than the N LOC in 1995, 2002, 2005, and 2007. Total sulfur deposition was well below the LOC for the same period. Total N deposition in Yellowstone National Park has ranged from 1.39 to 2.18 kg/ha-year, and total sulphur deposition has been about 1 kg/ha-year. Total N deposition at Centennial has ranged from 2-4 kg/ha-year, and total sulphur deposition has been below 3 kg/ha-year.

Lake Chemistry

Long-Term Lake Monitoring for the Bridger-Teton National Forest

The lake monitoring program on the BTNF began in 1984 to monitor AQRVs in a Class I wilderness area. The four lakes (Black Joe, Hobbs, Upper Frozen, and Deep Lakes) that are currently monitored were chosen based on elevation (above 2,900 meters), size (greater than 15 acres), and low acid neutralization capacity (ANC) (Table 3-8). Chemical analyses are conducted at the Forest Service Air Resource Management (ARM) Laboratory in Fort Collins, Colorado (http://www.fs.fed.us/ waterlab/). Lake data for the BTNF can be obtained from the Forest Service Natural Resource Information System (NRIS)-Air database for chemistry of lakes, streams, and bulk deposition on and near the National Forests (http://www.fs.fed.us/waterdata/). The lake sampling followed protocols highlighted in the BTNF Wind River Mountains Air Quality Monitoring Program Methods Manual (Forest Service 2002b). Lakes were typically sampled three times per year at the inlet and outlet. Collecting of the season one sample occurred during the months after ice typically begins to break up (May to July 21). Season two sampling occurred mid- to late summer when the lakes typically are stratified (July 22 to August 31). Lastly, season three sampling occurred closest to typical lake freezing after fall overturn (September 1 to mid-November). In addition, epilimnion and hypolimnion samples were collected during season two.

Table 3-8. Physical Features of Sampled Lakes

Lake Name	Elevation (m)	Depth (m)	Area of Lake (acres)
Black Joe	3,120	29	80
Deep	3,220	27	61
Hobbs	3,080	18	17
Upper Frozen	3,490	43	24

Data from Black Joe, Hobbs, Deep and Upper Frozen Lakes were analyzed for trends in concentrations of lab specific conductance (Lcond), ANC (μeq/L), calcium (Ca^{2+}), chlorine (Cl^-), potassium (K^+), magnesium (Mg^{2+}), sodium (Na^+), NH_4^+, NO^-, lab pH, and SO_2^- (all in μeq/L). Data from each lake was analyzed for annual trends in chemistry at the lake inlet, outlet, epilimnion, and hypolimnion (hypo) in the General Technical Report (RMRS-GTR-248WWW) from Rocky Mountain Experiment Station in November 2010. Upper Frozen Lake was first sampled in 2000 and was later added as a very sensitive (low ANC) lake. Due to a short sampling period, statistical analysis could not be completed. Due to its remote location, Upper Frozen Lake was sampled once a year at the outlet during season two. General Trend Information for the long-term lakes is displayed in Table 3-9.

Table 3-9. Significant Trends for Long-Term Lakes (1984-Present)

	Black Joe			Hobbs			Deep			Upper Frozen		
	Inlet	Outlet	Hypo	Inlet	Outlet	Hypo	Inlet	Outlet	Hypo	Inlet	Outlet	Hypo
ANC	—	—	—	—	▼	—	—	—	—	ND	ND	ND
NH4	—	▲	▲	▲	▲	▲	—	—	▲	ND	ND	ND
NO3	▲	—	—	—	—	▼	—	—	▲	ND	ND	ND
SO4	▲	—	—	—	—	—	—	—	—	ND	ND	ND

ND = Not Determined — = No change
▲ = Increasing trend ▼ = Decreasing trend

Lake Trend Discussion

Black Joe Lake has increases of NO_3^- and SO_4 at the inlet. This indicates that the lake is getting additions of these nutrients due to atmospheric deposition and subsequent runoff entering the lake. This lake also shows increases in NH_4^+at the outlet and hypolimnion, which is likely a byproduct of dying algae and enrichment by additions of NO_3^- and SO_4. This lake is showing signs of nutrient enrichment tending towards eutrophication. In addition to atmospheric deposition as a source for enrichment, the melting of adjacent snowfields could be a stored source of nutrients that are being released as the snow melts. Snowfields have all but disappeared over the last 15 years.

Hobbs Lake is truly showing signs of eutrophication with NH_4^+ increasing at the outlet, inlet and hypolimnion. This lake is also showing decreases in NO_3 at the hypolimnion, which indicates NO_3^- is probably being taken up by biota in the lake system. This lake also shows a decrease in ANC or less ability to buffer the addition of acids to the lake. Low ANCs may contribute to changes in biota within the lake system and can be harmful to fish. These nutrient increases are due to increased atmospheric deposition as shown by co-located deposition monitors.

Deep Lake is showing enrichment in the form of NO_3^- and NH_4^+ in the hypolimnion. The source is likely atmospheric deposition. This lake (like Black Joe Lake) is showing signs of nutrient enrichment trending towards eutrophication.

Upper Frozen Lake has a limited number of samples, and not enough data is available for statistical analysis.

More significant trends appeared in the inlet samples rather than in the outlet samples, most likely due to lake watershed processes such as biological activity and mixing. Black Joe and Deep lakes may be particularly influenced by melting snowfields and atmospheric deposition. Chemical concentrations in lakes may be influenced by weather and the time of year samples were collected since lake chemistry is increasingly influenced by groundwater after the snowmelt surge is over (Guerri 2010, personal communication).

An increasing trend in NO_3^- concentration was also found in lakes that were sampled in the Shoshone National Forest (Bevenger 2008). In the Rocky Mountains, many lakes may be at or near N saturation levels (Burns 2003, Campbell 2004) where lake N supply exceeds uptake. Increasing trends in NO_3^- concentrations have occurred in at least two water catchments in the Colorado Front Range (Williams et al. 1996). In these two catchments, NO_3^- levels have increased from below detection limits to about 10 µeq/L (0.62 mg/L). NH_4^+ concentrations have also been increasing at Black Joe, Hobbs, and Deep lakes. Significant increasing trends were present in the hypolimnion at Black Joe and Deep lakes, the inlet and outlet at Hobbs Lake, and the outlet at Black Joe Lake. The major concern associated with increasing inorganic N in aquatic ecosystems is the potential to cause acidification (via increasing hydrogen ions) and/or eutrophication through increased primary producers (Camargo and Alonso 2007).

The data suggest an increasing trend in SO_4^{2-} at Upper Frozen and Black Joe lakes. This is opposite the pattern of decreasing trends in SO_4^{2-} concentrations observed in precipitation across the United States, including the trends found in the NADP data discussed above and in Hobbs Lake. SO_4^{2-} concentrations in lake water may be influenced by melting snowfields (with the exception of Hobbs Lake) or local and/or regional emissions. In the neighboring Shoshone National Forest, Bevenger (2008) found no significant trends in SO_4^{2-} at Saddlebag Lake and significant decreasing trends at Ross Lake for the outlet and hypolimnion. On the other hand, some lakes in Colorado are exhibiting increases or no trend in SO_4^{2-} concentrations when analyzed (Mast 2009, personal communication). The cause of the increased trend in SO_4^{2-} in the Bridger-Teton lakes is not readily understood. Overall, cations (Na^+, Ca^{2+}, Mg^{2+}, and K^+) showed significant increases in concentrations over time in some portions of the lakes possibly due to drought, melting snowfields, or both.

General observations from the data:

- SO_4^{2-} has been increasing (hypolimnion) since the late 90's;
- Increase in NH_4^+ in lakes (agrees with the general increase in NH_4^+ deposition occurring across the western US);
- Increase in NO_3^- during season three lake sampling for Black Joe and Deep inlets;
- Hobbs Lake appears to be the lake most impacted by additions of N;
- Deep Lake appears to be using additions of N (increasing in the hypolimnion);
- Both Black Joe and Hobbs Lakes are showing increases in NH_4^+ at the outlets, which may contribute to changes downstream; and
- SO_4^{2-} and N loading are higher in lakes on the south end of the Wind River Range.

These observations lead us to conclude that the chemistry and function our long-term lakes are changing due to increased deposition of N and SO_4^{2-}. Increases in hypolimnion and outlet NH_4^+means there is some eutrophication occurring (Black Joe, Hobbs and Deep Lakes). Nitrogen and sulphur concentrations are much higher in inlets than in outlets (indicating nutrient uptake in the lakes). A N spike in the inlet compared to the outlet meets the definition of eutrophication and represents a build-up in N entering the lakes. All of these are of concern since minor changes in lake chemistry can change the function and survival of biotic communities within the lake ecosystem and even downstream. Biota within the lake ecosystem that can be affected include algae, diatoms, macroinvertebrates, and fish. Future deposition of N and sulphur compounds must be reduced to avoid even more drastic changes from occurring, so Federal Land managers can fulfill their obligations under the Clean Air Act (CAA) to protect AQRVs in Class I Wilderness areas.

3.2.6 Summary of Existing Air Quality

Air quality monitoring data provided by the State of Wyoming show that air quality in the planning area is not entirely in compliance with state and federal ambient air quality standards (Table 3-10).

Table 3-10. Summary of Air Quality Values for the Planning Area

Air Quality Component	Comment
Air Pollutant Concentrations	
Criteria air pollutants	• Concentrations of CO, NO2, PM and SO2 are in compliance with NAAQS and WAAQS. • All of Sublette and parts of Lincoln and Sweetwater counties have been designated non-attainment for O3. • Sheridan County has been designated non-attainment for PM, but monitored concentrations have been in compliance with the NAAQS for many years.
Nitrogen compounds	• Concentrations of HNO_3, NO_3^- and NH_4^+ in the planning area are consistent with other remote areas.
Sulfur compounds	• SO_2 concentrations in the planning area are below concentrations typical in remote areas. • SO_4^{--} concentrations in the planning area are below concentrations typical in remote areas.

Air Quality Component	Comment
Visibility	
Annual Visibility	• Visibility in Bridger Wilderness, Yellowstone National Park and Rocky Mountain National Park has improved slightly over the last two decades. • Visibility in North Absaroka has stayed about the same. • Visibility in Cloud Peak on hazy days has improved slightly, while visibility on average and clean days has stayed about the same.
Atmospheric Deposition	
Precipitation pH	• There was a slight precipitation acidification in Pinedale from 1994 through 1998 (pH as low as 4.9).
Total deposition	• Pinedale: Total N deposition above LOC (1.5 kg/ha-year) for some years. Total sulphur deposition below LOC. • Yellowstone National Park: Total N deposition above LOC for most years. Total sulphur deposition below LOC. • Centennial: Total N deposition above LOC for most years. Total sulphur deposition below LOC.
Lake Chemistry: Acid Neutralizing Capacity (Forest Service 2010)	• Black Joe: Current ANC 69.7 µeq/l, flat trend from 1984 through 2010. • Hobbs: Current ANC 70.1 µeq/l, decreasing trend from 1984 through 2010. • Deep: Current ANC 60.4 µeq/l, flat trend from 1984 through 2010. • Ross: Current ANC 54.1 µeq/l, decreasing trend from 1984 through 2010. • Lower Saddlebag: Current ANC 55.6 µeq/l, decreasing trend from 1984 through 2010. • Upper Frozen: Current ANC 7.4 µeq/l (extremely sensitive to atmospheric deposition). • Lazy Boy: Current ANC 12.4 µeq/l (extremely sensitive to atmospheric deposition).

3.2.7 Global Climate Change

Ongoing scientific research has identified the potential impacts of greenhouse gas (GHG) emissions (including carbon dioxide [CO_2], methane [CH_4], nitrous oxide [N_2O], water vapor, and several trace gases) on global climate. Through complex interactions at regional and global scales, these GHG emissions cause a net warming effect of the atmosphere (which makes surface temperatures suitable for life on Earth), primarily by decreasing the amount of heat energy radiated by the Earth back into space. Although GHG levels have varied for millennia (along with corresponding variations in climatic conditions), recent industrialization and burning of fossil carbon sources have caused CO_2 concentrations to increase dramatically and are likely to contribute to overall climatic changes. These overall climate changes are typically referred to as global warming or global climate change. Increasing CO_2 concentrations also lead to preferential fertilization and growth of specific plant species.

Several activities occur within the planning area that may generate GHG emissions. Oil and gas development, large fires, and recreation using combustion engines can potentially generate CO_2 and CH_4. Without additional meteorological monitoring systems, it is difficult to determine the spatial and temporal variability and change of climatic conditions, but increasing concentrations of GHG are likely to accelerate the rate of climate change.

Global mean surface temperatures increased nearly 1.0°C (1.8°F) from 1890 to 2006 (Goddard Institute for Space Studies 2009). Observations and predictive models indicate that average temperature changes are likely to be greater in the Northern Hemisphere. Figure 3-44 shows data indicating that northern latitudes (above 24° N) have exhibited temperature increases of nearly 1.2°C (2.1°F) since 1900, with nearly a 1.0°C (1.8°F) increase since 1970 alone. Figure 3-45 shows average temperature (AT) and precipitation (PPT) trends for the conterminous United States. For both parameters, varying rates of change have occurred, but overall, there have been increases in both AT and PPT. Temperatures in southwestern Wyoming have increased by 0.25 to 0.4 F° per decade since 1976 and precipitation has decreased by 0.3 to 0.6 inches per decade since 1976.

In 2001, the Intergovernmental Panel on Climate Change (IPCC) pointed out that by the year 2100, global average surface temperatures would increase 1.4 to 5.8°C (2.5 to 10.4°F) above 1990 levels (IPCC 2007). The National Academy of Sciences (2008) confirmed these findings but also indicated that there are uncertainties regarding how climate change may affect different regions. Computer model forecasts indicate that increases in temperature will not be evenly or equally distributed but rather are likely to be accentuated at higher latitudes. Warming during the winter months is expected to be greater than during the summer, and increases in daily minimum temperatures are more likely than increases in daily maximum temperatures.

3.2.8 Cooperative Air Quality Management

The State of Wyoming has primacy with regard to air quality regulation within Wyoming. Adhering to WDEQ standards is required by law. Air quality standards are maintained by the State of Wyoming, which determines the necessity of regulating emissions. When necessary, the state regulates emissions through its State Implementation Plan (SIP) for air quality by promulgating the appropriate rule. Federal Land Managers such as the BLM and Forest Service strive to minimize, within the scope of their authority, any emissions that may add to atmospheric deposition, cause violations of air quality standards, or degrade visibility. The EPA provides oversight responsibility during this process and has approval authority over the State of Wyoming SIP. State standards enforced in the planning area must be as strict as or stricter than federal standards.

The BLM and the Forest Service help support interagency efforts, such as IMPROVE stations and remote automated weather stations (RAWS), and directly fund the WARMS network.